APPLICATION OF ECONOMIC PRINCIPLES IN ENERGY CONSERVATION MEASURES

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Introduction

With energy likely to become increasingly scarce in the future, it is important to understand how it is used in society so that steps may be taken to reduce the energy required to maintain a given quality of life. In a capitalist economy, the interplay of supply and demand determines an equilibrium market price for scarce resources. Our society seems, however, to have decided that energy conservation should not just be left to this interplay. Instead, policy makers at enterprise level are called on to play a role in identifying those actions, technologies or devices that may have energy-conserving potential, in supporting their development, and in encouraging their timely and widespread adoption.

For their role to be effective, policy makers at enterprise level must have and be willing to use - some economic tools that permit estimation of the costs and benefits of their actions. Costs may consist of funds spent on installation, operation, maintenance, research and development and public education, of administrative expenses of an energy conservation retrofit etc. Benefits arise mainly through the fast adoption of energy- conserving technologies with their attendant energy and economic savings .

The formulation of a an energy conservation policy at the enterprise level requires that the issues involved be fundamentally analyzed. Information transfer, more contribute to reduced energy use. Our major choice, however, is between producing the present mix of materials, commodities, and services more efficiently or decreasing demand for them. The first option is referred to as the "technical fix", the second one as "change of lifestyle". If the first option fails, the change in life style might become mandatory.

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* In evaluating these savings, policy makers may assign "shadow price" (or opportunity cost of resources) different from observed market prices to certain energy forms, to reflect more correctly their perceived value to society (for details see Glossary).

The main purpose of this paper is to show what special economic tools are required to evaluate one or several energy conservation measures, and to demonstrate application of these economic tools. The paper will deal with technical fix approach. A review of the existing literature and highlights of model structure of economic tools will be presented in subsequent sections. An attempt will be made to integrate one such economic tool, known as Life Cycle Costing (LCC) or equivalent present value criterion with another tool known as Market Acceptance approach.This integrated approach, however, is uncommon in existing literature. A prototype example will be put forth to establish our proposed integration. A Glossary is provided at the end to explain different technical terms used extensively throughout our discussions. The explicit treatment of risk and uncertainty is beyond the scope of the present paper.

Higher capital investment that might be necessary for energy conservation retrofit can lead to a decrease in direct use of energy (capital and energy are substitutable). Both the cost and energy involved in these investments can be analyzed along a conservation path which is the locus of cost vs energy, when the energy utilisation process is changed in the direction of the thermodynamic limit, according to a specified change in equipment, while the total production rate is maintained.

A conservation path for energy does not necessarily mean a reduction in cost. When a piece of equipment is designed (subject to technological options) to optimize direct energy use and investment (with respect to total cost), a change in the process parameter will usually mean an increase in capital cost (usually operating cost goes down with initial capital investment).

Review of Economic Tools

A rational policy maker at enterprise level in the sphere of energy conservation envisages a six step evaluation process:

(i) Identification of systems worthy of encouragement with the help of LCC technique;

(ii) Determination of the likely Market Acceptance of these systems (in quantity and over time) due only to the interplay of normal market forces (it will be shown later that Market Acceptance technique goes beyond LCC in choosing right type of system for the user concerned);

(iii) Designing a set of policy measures that would encourage Market Acceptance of the systems;

(iv) Determination of the likely consequences of various policy measures designed to encourage Market Acceptance;

(v) Assessment of the costs and benefits of various measures and examination of whether consumer welfare as well as the welfare of society served;

(vi) Final selection of systems to be encouraged and of measures to accomplish this.

Life Cycle Costing (LCC) or present value criterion) is useful in the evaluation of both the energy consumption and of the overall costs of competing service delivery systems (steps (i), (ii), (iii) and (iv)) above. It is simply a consistent way of comparing competing systems for delivery of a service by reducing their costs of ownership (interest and amortization for financing the acquisition (debt service), property taxes etc.) and operation to a single number, expressed in terms of rupees of present value. This technique is an outgrowth and application of a branch of economics called the theory of investment. It received major impetus over fifty years ago from the work of such economists as Wicksell (1934). Modern treatments with extensive bibliographies are given by Hirshleifer (1970), Smith (1961), Friedrich and Lutz (1951).

A second technique, the estimation of Market Acceptance applies similarly to steps (ii), (iii) and (iv) above. It is based on an evaluation of the factors that influence the dynamics of technological change. One of these factors is, of course, system cost (initial capital investment of the system). Studies of technology change combine economic theory with techniques of econometrics viz., Blackman (1974), Mansfield (1961), Salter (1964), Solomon (1963)).

Finally, Cost-Benefit (CB) technique is a well-documented application of economic thinking to the overall evaluation of competing projects (e.g., UNIDO Guidelines (1972), Little and Mirrlees (1974), Layard (1976), Mishan (1975)). This paper will not deal in detail with CB analysis which is in the public domain.

It is worthwhile to mention that above three techniques are widely used in energy conservation measures both at energy producer and energy consumer ends. Here we are concerned solely with the demand side of the problem i.e. with durability (or life), its costs and benefits, as viewed by the purchaser of energy conserving equipment.

The procedure is to compare two systems (say systems A and B) at a time. The first step is to determine if A conserves "valuable" energy in comparison with B in delivering a unit of service. The emphasis is on the word "valuable". Not all Btu's are equivalent (e.g., the Second Law of Thermodynamics teaches us that high-grade energy such as high-temperature heat and electricity can be converted into work more efficiently than lower grade energy. Moreover, oil and gas may be more valuable, hence worth conserving for feedstocks, etc., than coal, because less of the former are available domestically). Finally not all Btu's cost the same.

Thus, the value of the energy conserved by using A in lieu of B should be determined. In the second step, this value may be arrived at by weighting each Btu spent or saved with its (market or shadow) price. (Here the shadow price may reflect a premium imputed to a unit of energy resource by virtue of its scarcity value, cost, or more generally because of its perceived social value. See Glossary for further details).

Moreover, different amounts and forms of energy have been embodied in the energy conserving equipment that deliver the energy flow for our two systems (A and B), which may not be equally durable. It is, therefore, imperative to use energy accounting system which takes into account not only amounts and costs of energy consumed in running the systems, but also those embodied in their capital goods. Since durability or life of capital equipment may differ for the pair of systems, it is worthwhile to combine the two types (capital and operating) of costs into a single figure for each system. This is precisely what Life Cycle Costing (LCC) accomplishes in evaluating energy as well as total costs of the two systems. LCC is used to combine one-time first costs on the one hand, and periodic owning and operating costs on the other.

A lower total system cost for A than for B militates in favour of acceptance for A. It is possible to devise an index (with respect to time) for the relative costs of the two systems to explain the dynamics of Market

Acceptance. The derivation of such an index (e.g., attractive index) will be shown later in this paper.

If certain measures promise to be effective in encouraging Market Acceptance, they should be examined from the social perspective. In particular, one must ask whether these measures serve consumer/producer welfare and equity to first order. A more comprehensive investigation of the benefits and costs (C B technique) of these measures to society as a whole is well advised. This will force a systematic look at questions of incidence and equity, as well as the methods for financing the measures, at their administrative costs, and at their overall desirability. The C B studies are usually intended to single out the optimal assortment of projects that can be carried out under a budget constraint. It must be preceded by a C-B comparison of various alternative energy conserving measures.

Life-Cycle Costing (LCC)

Life cycle costs are the acquisition and running costs associated with an energy conserving equipment expressed in terms of their present value. Let t be the time (years), LCC the life cycle cost, ALCC, its equivalent annual value, P the price, fP the first cost or down payment (initial cost that must be met at the time of, and as a condition of, a purchase) for the equipment, RC the running cost, made up of the variable and fixed components VRC and FRC respectively, r the discount rate, and T the service life. The r is the individual time preference rate for investment on the part of the user. This rate may be a function of income, age, family size, education, personal taste, size of downpayment of the user, present market interest rate on capital goods, etc.

We make the following simplifying assumptions:

(i) There are only two systems/projects A and B;

(ii) The energy flows and their qualities of A and B are identical;

(iii) Scrap or recovery values at the end of life are assumed negligible;

(iv) Discrete annual compounding is used.

The LCCs for the two systems are

$$(1)\qquad LCC_A = f_A P_A + \mathop{}\limits_{t=1}^{T_A} \frac{RC_A(t)}{(1+r)^t}$$

$$(2)\qquad LCC_B = f_B P_B + \mathop{}\limits_{t=1}^{T_B} \frac{RC_B(t)}{(1+r)^t}$$

where T_A = useful life of system A, in years

T_B = useful life of system B, in years

RC(t) includes owning and operating costs and can be any (given) function of time. If t is constant

$$(3)\qquad \mathop{}\limits_{t=1}^{T} \frac{1}{(1+r)^t} = \frac{(1+r)^T-1}{r(1+r)^T} = \frac{1}{CRF(r,T)}$$

or $$(4)\qquad LCC = fP + \frac{RC}{CRF(r,T)}$$

where CRF (r,T) is the capital recovery factor. Now, T equal annual payments in the amount of CRF, made in years 1,2.....T have a net present value of 1 when discounted to t = 0.

We can annualize LCC into T equivalent equal annual payments, ALCC.

$$(5)\qquad ALCC_A = CRF\ (r,T_A)LCC_A$$

$$(6)\qquad ALCC_B = CRF\ (r,T_B)LCC_B$$

We need to annualize LCC because total life cycle costs LCC_A and LCC_B are not directly comparable, unless T_A=T_B.

If t =, $T_A = T_B$, we get (by summation of GP series)

(7) $$LCC_A = LCC_A \qquad \frac{CRF(r,T_A)}{r}$$

(8) $$LCC_B = LCC_B \qquad \frac{CRF(r,T_B)}{r}$$

An user should choose the system which has the lower annualized life cycle costs.

In the above example, T is assumed to be given. For diminishing efficiency of an equipment e.g., boiler tube, an economic service life T can be determined endogenously. Consider the case in which a durable (e.g., energy conserving equipment) is replaced at the end of life by an identical new one of the same description. We need to minimize ALCC with respect to T. For small values of T, stretching the service life one more year would lower ALCC because first costs fP could be spread over more time. Later, as operating costs increase, they become dominant and drive up ALCC.

$$ALCC(r,T) = CRF(r,T)\ fP + \underset{t}{} \frac{FRC(t)}{(1+r)^t} + \overset{T}{\underset{t=1}{}} \frac{VRC(t)}{(1+r)^t}$$

Where FRC and VRC are fixed and variable running costs respectively. VRC represents cost that goes away if the system is permanently retired. FRC may vary in time but is fixed in the sense of being unalterable. FRC, thus, denotes cost which does not depend on system use, hence on its lifetime. This is indicated by leaving the summation limits on FRC open in equation (9). For example, amortization and interest charges would be fixed costs and would be incurred over the term of the loan; insurance and ad valorem taxes would be variable costs and would be incurred only during the period, T.

To derive the minimum value of ALCC, we would put d (ALCC) = 0 which imply (10) ALCC (r,T) VRC (T+1). -

The end of life T is reached when ALCC are minimized; this occurs when they approximately equal the annual variable costs associated with running the system in the next year T+1. Since the annual costs of investing in and running a new identical system in year T (and for a point T) are also ALCC (r,T), this is the well known result of economics : end of life is reached and new investment should be initiated when the short run marginal costs (of continuing to operate the old system) equals the long run marginal cost (of replacing the old system with a new one).

Consider now the case where system B is already installed and nearing the end of its life. Suppose a system A becomes available where $ALCC_A\ (r,T_A) < ALCC_B\ (r,T_B)$. Then policy will be earlier retirement or accelerated obsolescence of system B, i.e., to a lifetime $T'_B < T_B$ where T'_B is determined by

$$(11)\quad VRC_B\ (T'_B+1)\qquad ALCC_A\ (r,T_A)$$

which says that B is retired and A installed in the year T'_B of the life of system B in which the variable running costs for continuing B in operation are about to overtake the total annual life cycle costs for a new system A.

Suppose instead that there is competition from a system A such that $LCC_A\ (t=\ ) < LCC_B\ (t=\ )$. Assume that B is purchased in year 0, and that A becomes available in year t. The problem is to determine the optimal age $T'_B < T_B$ at which B is retired and investment in A takes place. It is assumed that after time T'_B, reinvestment in A occurs every T_A years out to $T=\ $. As viewed from year t, one has

$$(12)\quad LCC\ (t=\ ) = {}_{n=1}\frac{FRC_B}{(1+r)^n} + VRC_B\ {}_{n=1}^{T'_B-t}\frac{1}{(1+r)^n}$$

$$+\quad (f_A P_A\ +\ {}_{n=1}^{T_A}\frac{RC_A(n)}{(1+r)^n}\ \frac{1}{(1+r)^{T'_B-t}}\ \frac{CRF(r,T_A)}{r}$$

It can be rewritten as

$$LCC\ (T'_B)\ (t=\ ) = {}_{n=1}\frac{FRC_B}{(1+r)^n} + \frac{VRC_B}{CRF(r,T'_B-t)} + \frac{ALCC_A}{r}\ \frac{1}{(1+r)T'_B-t}$$

We can minimize $LCC\ (t=\ )$ by finding that value of T'_B for which $LCC\ (T'_B+1)\ (t=\ ) = LCC\ (T'_B)\ (t=\ )$. The result is (14) $VRC_B\quad ALCC_A$. If $ALCC_A < VRC_B$, $T'_B=t$: system A replaces B as soon as it is available, thus cutting useful life T'_B from its normal value T_B down to t.

If $ALCC_A > VRC_B$, $T'_B = T_B$: system A replaces B at the end of the latter's service life T_B. If $ALCC_A = VRC_B$, the takeover can take place anytime in the interval $t_B < T'_B < T_B$ with indifferent results.

So far, the appropriate discount rate r, has been assumed as given. One can, however get a rough idea of how r may vary with income of the user. Time preference rates for private businesses (also called internal rate of return or discount rate) have been estimated in economic literature at from 8% to 20% with 15% after taxes typical of recent values. Rates vary between businesses and between economic sectors. They depend on acceptable returns (after taxes) on current ventures, on predicted opportunities for future returns, and on current and projected future interest rates on borrowings. Periods of anticipated inflation are generally followed by high discount rates.

To make a complete evaluation of potential policy measures in regard to energy conserving equipment, one would have to include all taxes (central, state, property) tax write offs and credits (depreciation, interest, investment tax credit, etc), owning costs (insurance, mainten ance contracts, etc). inflationary factors, and financing. Our previous simple formulation can be broadened to include financing.

Since Pf is the downpayment for a system, an amount P(1-f) is to be financed (applicable for large energy conserving equipment) at (annual) interest rate i over a term of N years. One may derive the annual payments for interest and amortization. Annual payments can be taken as equal. The derivation can be based on a principal of Rs. 1; the annual amounts so derived can then be multiplied by P(1-f).

Market Acceptance

So far, we have developed a method for examining whether system A saves valuable energy in comparison with system B, being more attractive cost-wise to users. We have shown that the availability of A may shorten the economic service life of B, in a manner depending on whether B exhibits marked reduction in efficiency with age.

In practice, a competent system does not take over the moment it appears. In the first place, not all user/consumers see it as preferable even though it may have lower life cycle costs. In the second place, users may not know that the new system exists; they may perceive in it risks or innovative features that they are not ready to accept. Thus market penetration takes time. This is the starting point of our Market Acceptance technique.

By technology change we include quite generally any form of substitution of one process for another, one material for another or one good or service for another, provided the substitution affects resource use, cost of production and/or consumer utility. Economic theory postulates (see Mansfield (1961)) that one pioneering firm introduces an innovation which other firms gradually imitate. Mansfield considers the introduction and acceptance of 12 historical innovations, three for each four district industrial sectors in U.S.A. Introduction of an innovation means first use, not across-the-board adoption by a firm. The fraction of "hold-outs" introducing the innovation in a given time period, is an increasing function of the proportion of firms already using it and of the profitability of doing so, but a decreasing function of the size of the investment required. As an approximate measure of profitability, (   ) is defined as the ratio of the payback period for introduction of the innovation to a payback period that is considered acceptable by the industry. As an approximate measure for investment, S is defined as the ratio of the investment required to the net worth of the firm.

With the assumption of initial conditions, the fraction F of imitators grows logistically

(14A) $$F = (1 + A \exp(- \ ijt))^{-1}$$

Where A relates to the time at which half the imitators have been won over, and ij determines the dynamics,

(14B) $$ij = a_{11} + a_{12} \ ij + a_{13} S_{ij}$$

Where index 1 refers to the industrial sector, index J to the specific innovation in question (constant a_{11} is an innovation index related to firms). Actually because of the spareseness of data, a_{12} and a_{13} were estimated across all firms for four industrial sectors in U.S.A:

(14C) $$ij = a_{11} + 0.53 \ _{ij} - 0.027 \ S_{ij}$$

Correlation coefficient = 0.997

The constant a_{i1} is found to be always negative, ranges from -0.29 to -0.59. The smaller it is, algebraically the more sluggish the dynamics or innovation. Thus a_{i1} can be regarded as an industry innovativeness (risk-acceptance, imitativeness) index. The effect of profit on the dynamics is positive and extremely significant; the effect of size of investment is negative as expected.

It is however, clear that any viable innovation contributes to both producer and consumer (of energy innovation) ends. At the early stages of an innovation, especially of the producer good type, $_{ij}$ may most appropriately reflect the producers surplus or profit, and S_{ij} his capital investment. Capacity is as yet limited; the challenger (new producer of innovation) may permit him to retain earnings for future expansion. At a later stage, the challenger is taking over the market, and competition will cause major part of the surplus to be passed on to the buyer. If lower price causes demand to expand further surpluses result. At this stage, consumer/user acceptance determines the dynamics of substitution (system A and B for instance). One can attempt to unite the two viewpoints (i.e. that of the innovating manufacturing firm, and that of its customer) by defining the ratio of prices per unit for system A and B in analogy to earlier LCC technique as one of the salient variables for the dynamics of substitution. The two price stages can be simulated by a single Market-share (the fraction of a specific market expressed in terms of annual sales) weighted price. Market growth and capital obsolescence tend to drive the substitution forward A "learning" time constant (which may be related to parameter a_{i1} in equation (14B))may be introduced to reflect the combined inertia of production process, gradual achievement of economies of scale, and consumer education and habit alteration.

Thus, we can derive the following concise set of assertions:

(i) Change usually takes place through substitution. The process of substitution (system A for B or vice versa) goes to completion gradually over time in the market. Once well on the way, the process seldom reverses, unless some disruptive external change (oil embargo, OPEC cartel formation) takes place.

(ii) The dynamics of substitution (in energy conservation measures) may depend on a number of factors. The best authenticated of these factors is the cost or price competiteveness, in terms of producer and/or consumer surplus. It also depends on the size of the required producer and/or consumer investment. Here the ratio of investment to net worth or income has usually been taken as a measure.

Integration of LCC and Market Acceptance Technique

Most equipment which conserve energy in operation - and which society therefore wishes to see adopted more widely - are characterized by higher first costs than their competitors. It may be the case that even on an LCC basis, at energy market prices, the energy conserving equipment has only a slight edge over its competitors, while it may be preferable from the view point of energy conservation. Thus, we can think of system A (in line with our earlier discussion on LCC) which has higher first cost but lower running cost (say because of lower energy consumption per unit of service flow as in the case of a more efficient electric motor). By taking the difference of equations (5) and (6), we can see that a lower value of r makes the present value of savings in running costs from use of system A larger relative to the savings in first costs from use of system B. The annualized LCC savings are

$$(15)\ \mathrm{ALCCS}(r, T_A, T_B) = \mathrm{ALCC}_B\ (r, T_B) - \mathrm{ALCC}_A(r, T_A)$$

$$= \ (f_B P_B + \mathop{}\limits_{t=1}^{T_B} \frac{RC_B(t)}{(1+r)^t}\ ) \ \frac{r(1+r)^{T_B}}{(1+r)^{T_B}-1}$$

$$- \ f_A P_A + \mathop{}\limits_{t=1}^{T_A} \frac{RC_A(t)}{(1+r)^t}\ ) \ \frac{r(1+r)^{T_A}}{(1+r)^{T_A}-1}$$

Given P, f and RC(t) we can find the value of r* of r for which ALCCS (r) = 0. Since systems A and B are equally economical at the break-even discount rate r*, it follows that a discount rate r<r* favours the system A which has higher first costs but lower running costs than the system B.

Market Aceptance of system A in competition with B depends on the cost savings ALCCS (r) of equation (15). We can have an "attractive index",

(16) $AI(r, T_A, T_B) = r_1/r$ where r_1 is determined by $ALCC_A(r_1, T_A) = ALCC_B(r, T_B)$ as a convenient measure of the comparative attractiveness of system A relative to system B. If AI(r) is little greater than 1, the rate of Market Acceptance of A is likely to be sluggish, if AI(r) is more greater than 1, Market Acceptance will be rapid. For $r > r^*$, where $AI(r) < 1$, Market Acceptance is unlikely to take place at all.

We can write net energy LCC savings of system A relative to B as

(17) $ANELCCS(r_E, T_A, T_B) = ANELCC_B(r_E, T_B) - ANELCC_A(r_E, T_A)$

$$\text{i.e.,} \left(\sum_k \left(E^B_{ek} + \sum_{t=1}^{T_B} \frac{E^B_{rk}(t)}{(1+r_E)^t} \right) P_K \right) CRF(r_E, T_B)$$

$$- \left(\sum_k \left(E^A_{ek} + \sum_{t=1}^{T_A} \frac{E^A_{rk}(t)}{(1+r_E)^t} \right) P_K \right) CRF(r_E, T_A)$$

where E_{ek} is the energy of form K embodied in the equipment, P_K its price (it may be either a market price or an imputed shadow price reflecting the social value or cost of the Kth energy form e.g., a surcharge or excise tax imposed by government is an amount designed to bring down demand for energy form K to an acceptable level), $E_{ek}P_k$ represents downpayments, E_{rk} is the k annual consumption of energy of form K which may increase with age t due to diminishing efficiency, $\sum_k E_{rk}(t)\, P_k$ represents the running cost, r_E is the social discount rate.

If we put $P_k = 1$ in equation (17), we can obtain the net energy life cycle Btu savings from replacing a single system B by A. We can also solve for r_E^* the break even discount rate that reduces ANELCCS to zero. Generally, a social discount rate r_E of 0.08 + 0.02 is suggested in the literature.

We can use:

$$(18) \quad AI_E(r, T_A, T_B) = 1 + \frac{\text{ANELCCS}\ (r_E,\ T_A, T_B)}{\text{ANELCC}_A\ (r_E,\ T_A)}$$

as a measure for social desirability of A in comparison to B.

An Example

Assumed characteristics of two systems A and B are given below in Table 1 as an illustration.

Table 1 : Assumed Characteristics of Systems A and B

Sl No.	Data Item	System A	System B
1.	First cost including installation	Rs. 1,500.0	Rs. 3,500.0
2.	Component replacement every 5 years	-	Rs. 600.0
3.	Life time of installation	30 years	25 years
4.	Assumed energy embodiment of the system	2×10^7 BTU	3×10^7 BTU
5.	Energy embodied in component replacement	-	7.5×10^6 BTU
6.	Annual energy input (fuel equivalent)	2×10^8 BTU	1×10^8 BTU
7.	Annual energy input (electric)	20,000 KWHR	10,000 KWHR
8.	Annual cost of energy	Rs. 800.0	Rs. 400.0
9.	Other O & M & repair costs	Rs. 50.0	Rs. 100.0

To evaluate net energy savings, equation (17) is computed with $P_k = 1$ for all K. A social discount rate r_E of 8% is assumed. Equation (17) gives the annualised savings ANELCCS per system in BTU. Annualised energy savings can be expressed as a percentage by dividing by the annualised energy consumption of system B. A figure of comparative attractiveness AI_E (based on BTU) can be derived from equation (18). The energy savings from substituting A for B,

(16) $AI(r,T_A,T_B) = r_1/r$ where r_1 is determined by $ALCC_A (r_1, T_A) = ALCC_B (r, T_B)$ as a convenient measure of the comparative attractiveness of system A relative to system B. If AI(r) is little greater than 1, the rate of Market Acceptance of A is likely to be sluggish, if AI(r) is more greater than 1, Market Acceptance will be rapid. For $r>r^*$, where $AI(r) <1$, Market Acceptance is unlikely to take place at all.

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$$- \left({}_{k} \left(E^{A}_{ek} + {}^{T_A}_{t=1} \frac{E^{A}_{rk}(t)}{(1+r_E)^t}\right) P_K\right) CRF (r_E, T_A)$$

where E_{ek} is the energy of form K embodied in the equipment, P_K its price (it may be either a market price or an imputed shadow price reflecting the social value or cost of the Kth energy form e.g., a surcharge or excise tax imposed by government is an amount designed to bring down demand for energy form K to an acceptable level), $E_{ek}P_k$ represents downpayments, E_{rk} is the k annual consumption of energy of form K which may increase with age t due to diminishing efficiency, k $E_{rk}(t)\ P_k$ represents the running cost, r_E is the social discount rate.

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6.	Annual energy input (fuel equivalent)	$2x10^8$ BTU	$1x10^8$ BTU
7.	Annual energy input (electric)	20,000 KWHR	10,000 KWHR
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9.	Other O & M & repair costs	Rs. 50.0	Rs. 100.0

To evaluate net energy savings, equation (17) is computed with $P_k = 1$ for all K. A social discount rate r_E of 8% is assumed. Equation (17) gives the annualised savings ANELCCS per system in BTU. Annualised energy savings can be expressed as a percentage by dividing by the annualised energy consumption of system B. A figure of comparative attractiveness AI_E (based on BTU) can be derived from equation (18). The energy savings from substituting A for B, discounted to the present, are obtained by dividing the annualised savings by 0.08. With the values of Table 1, we can obtain:

$$\text{ANELCCS} = \text{ANELCC}_B - \text{ANELCC}_A$$

Where $$\text{ANELCC}_B = \left(2\text{X}10^7 + \sum_{t=1}^{30} \frac{2\text{x}10^8}{(1.08)^t}\right) 0.08883 = 2.018\text{x}10^8 \text{ BTU}$$

$$\text{ANELCC}_A = \left(3\text{x}10^7 + \sum_{n=1}^{4} \frac{7.5\text{x}10^6}{(1.08)^{5n}} + \sum_{t=1}^{25} \frac{1\text{x}10^8}{(1.08)^t}\right) 0.09368$$

$$= 1.040 \text{ x } 10^8 \text{ BTU}$$

The middle term of RHS of ANELCC_A equation is due to the periodic component replacements after years 5, 10, 15 and 20. The sum can be written as $7.5\text{x}10^6\ (\text{CRF}(1.08^5-1,\ 4))^{-1}$. These expressions give the energy savings in raw net BTU. Thus, equations yield annualized energy savings of $0.978\text{x}10^8$ BTU or [illegible] per system. The comparative attractiveness I_E becomes 1.940 based on BTU savings.

The life cycle costs for the two systems can be computed with the help of equation (9) with f=1 and zero fixed costs.

$$\text{ALCC}_A = \text{CRF}(r,25)\left(3500 + \sum_{n=1}^{4} \frac{600}{(1+r)^{5n}} + \sum_{t=1}^{25} \frac{500}{(1+r)^t}\right)$$

$$\text{ALCC}_B = \text{CRF}(r,30)\left(1500 + \sum_{t=1}^{30} \frac{850}{(1+r)^t}\right)$$

The terms with summation signs represent the variable components reduced to precent value.

We can see how the total annualized LCC for systems A and B vary with r. For low values of r, system A has lower LCC, but not low enough (> Rs. 850 per year = VRC_B)to satisfy condition (14) unless r> 0.05, a value lower than the likely perceived time preference rate of purchaser. Thus, accelerated obsolescence will be unlikely to occur. The break even discount rate becomes 0.12. If representative individual time preference rate (say r_o) is taken to be 0.20, our attrativeness index, AI becomes 0.78. We may conclude that system A is unlikely to find market acceptance under no financing circumstances. However, dynamics of substitution may change under attractive financial incentives which are beyond the scope of the paper.

Conclusion

The point of departure for the selection of any energy-conserving policy is the availability of (at least) two practical options or alternatives for policy maker at enterprise level. In real life, in the same point of time, or in the same geographical location, there could be several energy conservation options for the same industrial process. One need only set up a pairwise comparison of two options at a time and answer the question: which option is the most desirable from the energy conservation standpoint? Which option is the most desirable from the purchaser's point of view? If one takes both these factors into account, which option is socially the most desirable?

We have explained two economic techniques (LCC, Market Acceptance) and their integration to compare two systems at a time. To begin with, a policy maker at enterprise level can carry out LCC. As technology progresses over-time, Market Acceptance estimation may be warranted. Finally, C-B analysis may be applied to overall evaluation of competing projects which have involvement of large social groups, and wider foreign exchange implications.

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GLOSSARY

ACCELERATED OBSOLESCENCE:

Retirement of an equipment before the end of its "normal" service life because of technology change. Here the normal service life is determined by how long the equipment would optimally be put to a given use before being replaced by a new equipment of the same type.

AD VALOREM TAX:

An indirect tax (which is levied on expenditure) which is expressed as a proportion of the price of a good (an article of trade) - hence it is "by value".

AMORITIZATION:

Provision for the repayment of debt by accumulating a "Sinking fund" through regular payments which, with accumulated interest, may be used to settle debt in instalments over time, or in a lump sum. Rate of interest is the difference between what is lent, and what must be repaid after a specified period, expressed as a proportion of the amount lent.

ANNUALIZE:

To convert a one-time payment into "equivalent" equal annual instalments. Equivalent generally means instalments having a discounted present value equal to the one-time payment.

CAPITAL RECOVERY FACTOR:

The factor which annualizes a one-time payment in such a way that the discounted present value of all annual sums equals the one-time payments.

COST BENEFIT ANALYSIS:

An analysis of the benefits and costs of an action on project, including both direct and indirect effects, spillovers, and questions of incidence (the point at which the budren ultimately rests). The aim is to identify and measure the losses and gains in economic welfare which are incurred by society as a whole if the particular project in question is undertaken.

CONSUMER SURPLUS:

The difference between the total amount of money an individual would be prepared to pay for some quantity of a good, and the amount he/she actually has to pay. This is because there is "surplus" of satisfaction or utility from the consumption of the good which is not completely swallowed up by the total expenditure on the good, within a specified period of time.

DISCOUNT RATE:

The yearly rate at which future earnings or benefits should be reduced in order to yield their perceived present value; or the amount by which expenses incurred in a year from now should be reduced to yield the perceived costs today. In private industries, such a rate is usually inferred by comparisons with alternate opportunities for investing or borrowing. The break-even discount rate is the rate at which two competing systems exhibit the same annualized life cycle costs.

DYNAMICS:

The manner in which a quantity changes over time.

ELASTICITY:

In general terms, it is defined as a measure of degree of responsiveness of one variable to changes in another.

EMBODIED ENERGY:

Energy used to produce, transport, market and install an equipment as contrasted with the energy consumed in putting the good to use.

EQUITY:

Although the word is often used to signify a cash investment, as used here (in our paper) it means social justice or fairness in the spirit of the ideal of equal opportunity.

FIRST COSTS:

Initial costs that must be met at the time of, and as a condition of, a purchase.

FIXED RUNNING COSTS:

As used in our paper, running costs which must be met whether a system continues in use or is retired for good. In usual practice, fixed running costs refer to those that are independent of at what output level the system operates over the short run.

INCOME:

It is the flow of money or goods accruing to an individual, group of individual (private income), government (public income) over some time period.

INDIVIDUAL TIME PREFERENCE RATE:

The yearly rate at which individuals appear to discount future costs or returns, as inferred from their observed propensity for trading off present consumption against future return (or consumption).

INNOVATION:

The introduction of new products or production processes.

INSURANCE:

A contract to pay a premium in return for which the insurer will pay compensation in certain eventualities e.g., fire, theft, accident.

ISOQUANT:

A curve which shows the combinations of two inputs required to produce a given quantity of a particular product (good).

LEARNING TIME:

When a repetitive job is being done, it has been found empirically that as the production run proceeds, the time taken for each item decreases. Specifically, it may be shown that when the average time over a certain number of units is plotted against the serial number of items produced, the result is a straight line on a log-log grid. In practice, the rate of learning (which is given by the slope) must be derived from actual operating results.

LIFE CYCLE COSTING:

Evaluation of the costs of a "service" in terms of its initial acquisition costs and of its future (discounted) running costs. (Goods are mainly intangible and often consumed at the same time as they are produced. The services of an orchestra, a telephone call or a teacher are intangible. However, financial services or the work of a computing bureau are partially tangible in form e.g., a computer print-out sheet).

LOGISTIC FUNCTION:

A simple two parameter mathematical function of specific form and exhibiting a characteristic S-shape.

LONG RUN MARGINAL COSTS:

Those costs incurred when a long term investment (e.g., for new or replacement capacity) is made, expressed in terms of equivalent annual amounts and in terrms of one unit of capacity added or replaced.

MAINTENANCE COSTS:

Annual costs required (on the average) to maintain an equipment in operating condition.

MARGINAL CONSUMER:

The consumer (purchaser/user) who is indifferent (or undecided) as to whether he/she should acquire a system offered at a certain market price or not.

MARKET ACCEPTANCE:

The fraction of a specific market (expressed in terms of annual unit sales) that a given system has been able to penetrate at a given time.

NET ENERGY ACCOUNTING:

A method which takes embodied energy costs as well as running energy costs of a system into account.

OPERATING COSTS:

Cost incurred in the process of putting an equipment to use, such as energy and labour costs directly associated with the running of the same.

OPPORTUNITY COST:

The cost of putting a resource to a given use, as measured by the value foregone, because the resource has not been put to its best alternate use. The opportunity cost of inputs owned by a firm/producer which it supplies to itself, and which have alternative uses is called "Imputed Cost". In contrast, an accountant would define the cost of something as the total money expenditure or outlays necessary to achieve it. Opportunity cost will amount to the same thing as outlays, if and only if, the prices with which the outlays are calculated correctly reflect the value of alternative uses of the resources. Here price is defined as the quantity or money which must be exchanged for one unit of a good or service.

OWNING COST:

All the costs associated directly with ownership of a system. Apart from the first cost, these may include interest and amortization for financing the acquisition (debt service), insurance, property taxes etc.

PAYBACK PERIOD:

For a venture of positive net present value (the value of initial and subsequent expenses, revenues or net benefit streams, discounted to the present), the period of time (equal to or less than the service life) that must elapse before the discounted present value of all benefits upto that time equals the discounted present value of all costs (to the end of service life). Often, the simpler (undiscounted) ratio of full acquisition costs to annual net benefits (annual benefits net of annual costs) is taken as the payback period.

PRESENT VALUE:

The value of initial and subsequent expenses, revenues, or net benefit streams, discounted to the present.

PRODUCER GOODS:

Goods used principally in generating those goods and services which are offered to industries or individuals for "final consumption", e.g., machinery for extracting or refining resources, for fabrication and packaging of goods, and other forms of industrial and commercial capital.

PRODUCER SURPLUS:

Excess profit, or return to capital captured by all firms except the marginal one.

PRODUCTION FUNCTION:

A mathematical relationship between the quantity of output of a good and the quantities of inputs required to make it.

RETURN ON INVESTMENT:

Net average annual profit after taxes, divided by the investment. The rate of return can be computed as the discount rate which makes the present value of all future net returns during the operating life of a venture equal to the initial venture capital (or, in the case of financing, to its initial cost in present value terms); in that case it is often referred to as the "internal rate of return".

RUNNING COSTS:

As used in our paper, these include all periodic (annual fixed and variable) costs associated with owning and/or operating an equipment.

SYSTEM:

Any device, installation and/or set of procedures that provides a useful service over an extended period of time.

SERVICE FLOW:

The average annual benefit bestowed by a system when it is (sporadically or continuously) pressed into service.

SERVICE LIFE:

The period of time over which a newly installed system can be economically kept in its first intended use.

SHADOW PRICE:

An accounting price, not necessarily equal to market price, used to correct for effects not taken into account by the market at a given time. For example, a shadow price may correct for the fact that society attaches a premium to certain energy forms. Premium is the difference, where positive, between the current price or value and its issue price or par value.

SHORT RUN MARGINAL COSTS:

The costs associated with extending the service of a system in time or in output i.e., of running it for an additional year (rather than replacing it), or running it so that its annual output is increased by one unit (rather than investing in a unit of new capacity).

SOCIAL TIME PREFERENCE:

The discount rate perceived to be appropriate by our legislative representatives, acting as guardians of the long term survival, stability and health of society.

TECHNOLOGY CHANGE:

Change in the manner and/or used. In general, such change involves some innovation and substitution: substitution of one factor of production for another, of one machine or procedure for another, of one input material for another, or of one consumer good or service for another.

UTILITY:

The subjectively perceived benefit that a consumer derives from a good or service, as determined from observation of his/her willingness to pay for it, or to trade it off against other goods and services.

VARIABLE RUNNING COSTS:

As used here, those periodic costs associated with keeping a system in operation and/or in operating condition. This definition differs from the usual one, in which variable costs are exclusively those associated with the level of output, and disappear as output goes to zero even temporarily.